

Appendix B. Displays Included in the Handbook

As with controls, it was decided that including guidelines for all possible displays was not reasonable in a handbook that is tailored for the automated highway system. To determine which displays were to be included in the handbook, virtually the same methodology was used as was used for controls. First, a list of the factors relevant to displays use on the AHS was determined. Then, displays were rated on the evaluation factors and a simple score determined for each: unlike with controls, no display types were rejected a priori because of obvious incompatibility with the AHS. Although a weighted score would certainly have been better, there was no obvious basis for assigning realistic weights to the evaluation factors. Also, it should be noted that cost was not used to rate the displays. Although cost is clearly an important consideration, deciding how to use it as an evaluation factor was not clear. It may be that cost should be an initial filter through which a display type must pass to merit further consideration, or a final filter to decide between otherwise “equal” choices, but what cost cutoff should be used in any case was not obvious.

Evaluation Factors

The following factors were used to evaluate displays:

- How well does the display function in a dark environment?
- How well does the display function in a bright environment?
- How well does the display function with high background noise?
- Does the display have the ability to capture the user’s attention when he/she is not attending to it?
- Is the ability to get relevant information from the display contingent upon the user being in a particular location?
- Can the user get relevant information from the display if he/she is not looking at it?
- Can the display show graphics?
- Can the display show the same object in multiple colors, i.e., does it have a true color capability?
- How much space is required for the display, relative to the other displays being rated?
- Is the display operable over the anticipated temperature range that might be encountered in the AHS environment? This was taken to be approximately -34.4 °C to +54.4 °C (-30 °F to +130 °F).
- Does the display allow information to be shown in different ways (e.g., in different locations on its “face”)?

Displays Rated

The following displays were rated on the factors stated above:

- Analog/mechanical (e.g., gauges).
- Cathode ray tube.
- Counter/mechanical.
- Electroluminescent.
- Head-up display (where a particular technology was assumed to provide the imagery).
- Incandescent light.
- Light-emitting diode:
 - Simple indicator.
 - Segmented characters.
 - Matrix addressed.
- Liquid crystal display:
 - Reflective, segmented characters.
 - Reflective, matrix addressed.
 - Transflective: segmented characters.
 - Transflective: matrix addressed.
 - Transmissive: segmented characters.
 - Transmissive: matrix addressed.
- Plasma:
 - Segmented characters.
 - Matrix addressed.
- Speech.
- Simple tone.
- Vibration.
- Vacuum fluorescent display:
 - Segmented characters.
 - Matrix addressed.

The Ratings and Final Displays Selection

The ratings for each display stated above against each of the evaluation criteria are shown in table 41. To decide which displays to include in the handbook based on the ratings, it was necessary to determine a cutoff score below which a display would be eliminated from further consideration. There was no a priori basis for determining that score. Thus, the final selection was made after examination of the scores and discussion

Table 41. Displays tradeoffs.

	Salience in Low Ambient Illumi- nation	Salience in High Ambient Illumi- nation	Salience in High Ambient Noise	Attention -Getting Proper- ties	Visibility From Multiple Loca- tions	Usable With Eyes Busy?	Displays Graph- ics?	Displays Same Object in Multiple Colors?	Space Required	Oper- ability Over Tem- perature Range ¹	Flexible Formatting?	SCORE	Com- ment Key
	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	No = 0 Yes = 1	No = 0 Yes = 1	No = 0 Yes = 1	High = 0 Low = 1	Poor = 0 Good = 1	No = 0 Yes = 1		
Analog ²	1	1	1	0	1	0	0	0	1	1	0	6	a, e
CRT ³	1	0	1	0	1	0	1	1	0	1	1	7	h, i
Counter ²	1	1	1	0	1	0	0	0	1	1	0	6	a
EL ⁴	1	0	1	0	1	0	1	0	1	0	1	6	i, j
Head-Up Display ⁵	1	1	1	0	0	1	1	0	0	1	1	7	b, c, d, g, i
Incan- descent Light	1	0	1	0	1	0	0	0	1	1	0	5	
LED ⁶ : Simple Indicator	1	0	1	0	1	0	0	0	1	1	0	5	
LED ⁶ : Segment- ed Charac- ters	1	0	1	0	1	0	0	0	1	1	0	5 (Table contin- ued on next page.)	

¹ The anticipated temperature range is approximately -34.4 °C to +54.4 °C (-30 °F to +130 °F).² Mechanical (not including electronic representations).³ CRT = cathode ray tube.⁴ EL = electroluminescent. A matrix addressed display is assumed.⁵ Assumes a monochromatic, stroke cathode ray tube or vacuum fluorescent image source, and includes both refractive and holographic optics.⁶ LED = light-emitting diode.

Table 41. Displays tradeoffs (continued).

	Salience in Low Ambient Illumi- nation	Salience in High Ambient Illumi- nation	Salience in High Ambient Noise	Attention -Getting Proper- ties	Visibility From Multiple Loca- tions	Usable With Eyes Busy?	Displays Graph- ics?	Displays Same Object in Multiple Colors?	Space Required	Oper- ability Over Tem- perature Range ¹	Flexible Formatting?	SCORE	C r f
	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	No = 0 Yes = 1	No = 0 Yes = 1	No = 0 Yes = 1	High = 0 Low = 1	Poor = 0 Good = 1	No = 0 Yes = 1		
LED ⁶ : Matrix Address- ed Dis- play	1	0	1	0	1	0	1	1	1	1	1	8	
LCD ⁷ , Reflec- tive: Segment- ed Charac- ters	0	1	1	0	1	0	0	0	1	1	0	5	1,
LCD ⁷ , Reflec- tive: Matrix Address- ed Display	0	1	1	0	0	0	1	0	1	0	1	5	1,
LCD ⁷ , Trans- flective: Segment- ed Charac- ters ⁸	1	1	1	0	1	0	0	0	1	1	0	6 (Table contin- ued on next page.)	a,

⁷ LCD = liquid crystal display.⁸ Assumes incandescent, electroluminescent, or fluorescent edge lighting.

Table 41. Displays tradeoffs (continued).

	Salience in Low Ambient Illumi- nation	Salience in High Ambient Illumi- nation	Salience in High Ambient Noise	Attention - Getting Proper- ties	Visibility From Multiple Loca- tions	Usable With Eyes Busy?	Displays Graph- ics?	Displays Same Object in Multiple Colors?	Space Required	Oper- ability Over Tem- perature Range ¹	Flexible Formatting?	SCORE	Com- ment Key
	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	No = 0 Yes = 1	No = 0 Yes = 1	No = 0 Yes = 1	High = 0 Low = 1	Poor = 0 Good = 1	No = 0 Yes = 1		
LCD ⁷ , Trans- flective: Matrix Address- ed Display ⁸	1	1	1	0	0	0	1	0	1	0	1	6	a, i, j
LCD ⁷ , Trans- missive: Segment- ed Charac- ters ⁹	1	0	1	0	0	0	0	0	1	1	0	4	a, i, j
LCD ⁷ , Trans- missive: Matrix Address- ed Display ⁹	1	0	1	0	0	0	1	1	1	0	1	6	a, i, j
Plasma: Segment- ed Charac- ters	1	0	1	0	1	0	0	0	1	0	0	4 (Table contin- ued on next page.)	i, j

⁹ Assumes electroluminescent or fluorescent back lighting.

Table 41. Displays tradeoffs (continued).

	Salience in Low Ambient Illumi- nation	Salience in High Ambient Illumi- nation	Salience in High Ambient Noise	Attention - Getting Proper- ties	Visibility From Multiple Loca- tions	Usable With Eyes Busy?	Displays Graph- ics?	Displays Same Object in Multiple Colors?	Space Required	Oper- ability Over Tem- perature Range ¹	Flexible Formatting?	SCORE	Com- ment Key
	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	Poor = 0 Good = 1	No = 0 Yes = 1	No = 0 Yes = 1	No = 0 Yes = 1	High = 0 Low = 1	Poor = 0 Good = 1	No = 0 Yes = 1		
Plasma: Matrix Address- ed Display	1	0	1	0	1	0	1	0	1	0	1	6	i, j
Speech	1	1	0	1	1	1	0	0	1	1	1	8	f
Tone	1	1	0	1	1	1	0	0	1	1	1	8	f
Vibration	1	1	1	1	0	1	0	0	0	1	0	6	
VFD ¹⁰ : Segment- ed Charac- ters	1	1	1	0	1	0	0	0	1	1	0	6	i
VFD ¹⁰ : Matrix Address- ed Display	1	1	1	0	1	0	1	0	1	1	1	8 (Table contin- ued on next page.)	i

¹⁰ VFD = vacuum fluorescent display.

Comments

^a Assumes backlighting or transillumination.

^b Assumes stroke or matrix addressed imagery (raster imagery will have poor visibility in high ambient illumination).

^c Allows "eyes busy" use if the competing visual task involves the forward visual scene.

^d Color is possible, but not at adequate contrast levels.

Table 41. Displays tradeoffs (continued).

^e Check reading may be done from multiple locations, even with relatively small characters.

^f Ability to hear easily from multiple locations depends upon signal-to-noise ratio, competing speech tasks, and speaker (hardware) locations.

^g Downrated on space required due to protection optics.

^h Downrated on space required due to cathode ray tube depth.

ⁱ Contrast enhancement filters can improve visibility in high ambient illumination, but may degrade image quality.

^j An independent heating/cooling source can be added to improve operability under extreme temperatures.

among the authors and other human factors professionals at the authors' place of business. On that basis, it was decided that only displays with an unweighted score of six or above would be included in the handbook, with the exceptions noted below. Those displays are as follows:

- Analog/mechanical.
- Cathode ray tube.
- Counter/mechanical.
- Electroluminescent.
- Head-up display.
- Light-emitting diode, matrix addressed.
- Liquid crystal display:
 - Transflective, segmented characters.
 - Transflective, matrix addressed.
 - Transmissive, matrix addressed.
- Plasma, matrix addressed.
- Speech.
- Nonspeech auditory.
- Vacuum fluorescent display:
 - Segmented characters.
 - Matrix addressed.

In addition, it was decided to add simple indicator lights-incandescent and light-emitting diode-to the list. Given that simple indicators are used in a wide variety of applications, it was thought that there was a high likelihood they might be useful for the AHS in-vehicle interface.

Vibration, which had a score of six, was not included in the handbook for lack of appropriate information with which to provide guidelines.

When to Use Each Display

To help determine which display type to use in a particular situation, the information in table 42 is provided.

Table 42. Displays: when to use.

Display	When to Use
Analog/mechanical	<p>Analog indicators should be used in preference to digital readouts when the data displayed are of qualitative as well as quantitative value (when trends, direction of movement, and more-than-less-than relationships are of value as well as the specific numeric value), or of qualitative value only.</p> <p>They should not be used when the primary purpose is readout of precise quantitative information.</p>
Cathode ray tube (CRT)	<p>Cathode ray tubes should be used for text and graphics applications where display visibility from multiple viewer positions, high display brightness, high display mean time between failures, high display resolution, and a large range of display colors are more important than the display power consumption and physical display volume.</p> <p>Stroke written CRT's should be selected over raster CRT's when high symbol luminance is more important than the need to display filled or shaded objects and backgrounds.</p>
Counter/mechanical	<p>Mechanical counters should be used for presenting large ranges of quantitative data when users must make quick, precise readings but need not keep track of continuous trends.</p>
Electroluminescent (EL)	<p>Matrix-addressed EL displays should be used for graphics applications where display visibility from multiple viewer positions, high display uniformity, high display resolution, low physical display volume, and low power consumption are more important than the display of high brightness images, the luminance half-life of the display, or sunlight readability of the display.</p>
Head-up display (HUD)	<p>Head-up displays should be used in either of two circumstances First, if there is a need to present an electronic image conformal with (precisely overlaid on) the outside scene, HUD's are the most obvious way to address this need Second, a properly placed and collimated HUD may be used to decrease visual transitions from head-down displays to the outside, forward scene.</p>
Indicator lights	<p>Indicator lights should be used to indicate system, equipment, and/or control condition. They should be used to display qualitative information when an immediate reaction by the user is needed or to draw attention to an important system status.</p>
Light-emitting diode (LED), matrix addressed	<p>Matrix-addressed LED's should be used for graphics applications when display visibility from multiple viewer positions, low physical display volume, and high display mean time between failures are more important than high resolution, high brightness, low power consumption, and sunlight visibility</p> <p><i>(Table continued on next page.)</i></p>

Table 42. Displays: when to use (continued).

Display	When to Use
Liquid crystal display (LCD) <ul style="list-style-type: none"> • Transflective, segmented characters. • Transflective, matrix addressed • Transmissive, matrix addressed 	Transflective LCD's should be used where sunlight visibility, low power consumption, and display visibility from multiple viewer positions are more important than a multicolor, high resolution display. Transmissive LCD's should be used where display brightness, display resolution, and multicolor display are more important than sunlight visibility, low power consumption, and display visibility from multiple viewer positions. Seven-segment displays should be used only for applications requiring numeric information.
Plasma (gas discharge), matrix addressed	Matrix-addressed plasma displays should be used for graphics applications when display visibility from multiple viewer positions, low physical display volume, low power consumption, and high display mean time between failures are more important than high resolution, high brightness, the display of multicolored objects, and sunlight visibility.
Speech display	Speech displays should be used in situations where the user's eyes are busy or mobility is required. Avoid using a speech display when frequency of use is high, when multiple messages must be displayed simultaneously, or when the user would be expected to remember a series of instructions.
Nonspeech auditory display	Nonspeech auditory displays should be used under the following conditions: <ul style="list-style-type: none"> • The information that is to be processed is short, simple, and transitory, requiring an immediate or time-based response • The visual display is restricted by: <ul style="list-style-type: none"> • Overburdening • Ambient light variability or limitation • User mobility. • Degradation of vision (e.g., due to vibration) • Other environmental considerations. • Anticipated user inattention. • It is desirable to capture the user's attention. • Custom or usage has created the anticipation of an auditory display. • An auditory presentation is desirable to reinforce a visual presentation.
Vacuum fluorescent display (VFD) <ul style="list-style-type: none"> • Segmented characters. • Matrix addressed. 	Vacuum fluorescent displays should be used for character displays and graphics applications when display visibility from multiple viewer positions, high display brightness, low physical display volume, and high display mean time between failures are more important than the display of high resolution, multicolored objects. Seven-segment displays should be used only for applications requiring numeric information.